Risk mitigation of obsolescence for materials and processes as a consequence of sustainable development

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Scope

- Introduction to ESA
- Sustainable development at ESA
- The mission of the ‘Product Assurance and Safety Department’
- Approach for EEE components
- Review of ongoing activities in the area of M&P
- Conclusions

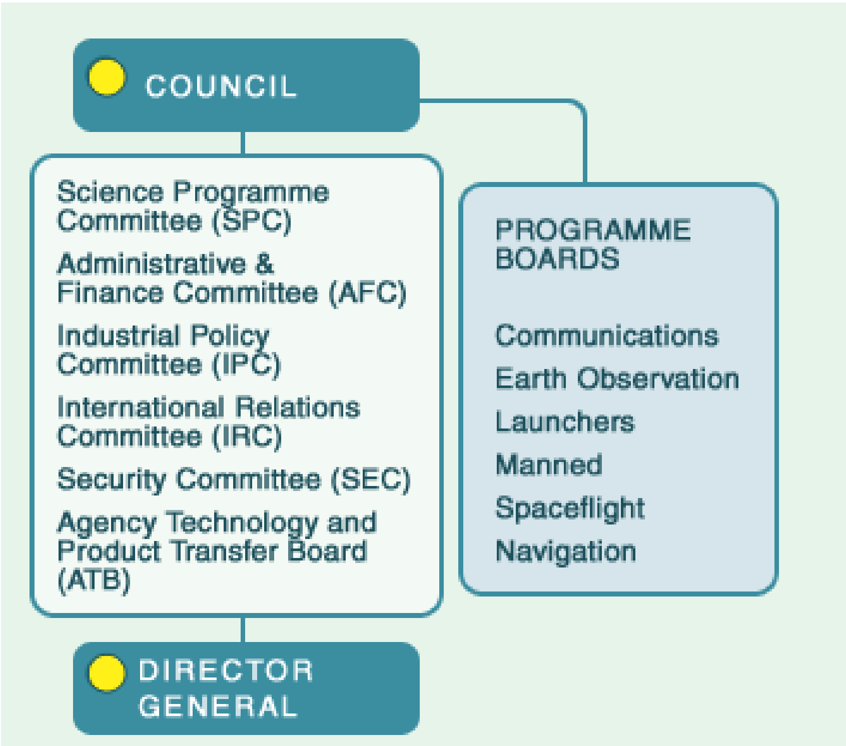
ESA – Member States

ESA has 18 member states

- Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Norway, the Netherlands, Portugal, Spain, Sweden, Switzerland and the United Kingdom.
- Hungary, Poland, and Romania are European Cooperating States.
- Canada takes part in some projects under a cooperation agreement.

	D	B	F	I	NL	GB	DK	E	S	CH	IRL	A	N	FIN	P	G	L	
2005																		
2000	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•			
1995	•	•	•	•	•	•	•	•	•	•	•	•	•	•				
1987	•	•	•	•	•	•	•	•	•	•	•	•	•					ESA
1975	•	•	•	•	•	•	•	•	•	•	•							
1973	•	•	•	•	•	•	•	•	•	•								
1962	•	•	•	•	•	•	•	•	•	•								ESRO
1962	•	•	•	•	•	•												ELDO

ESA – Governance Structure

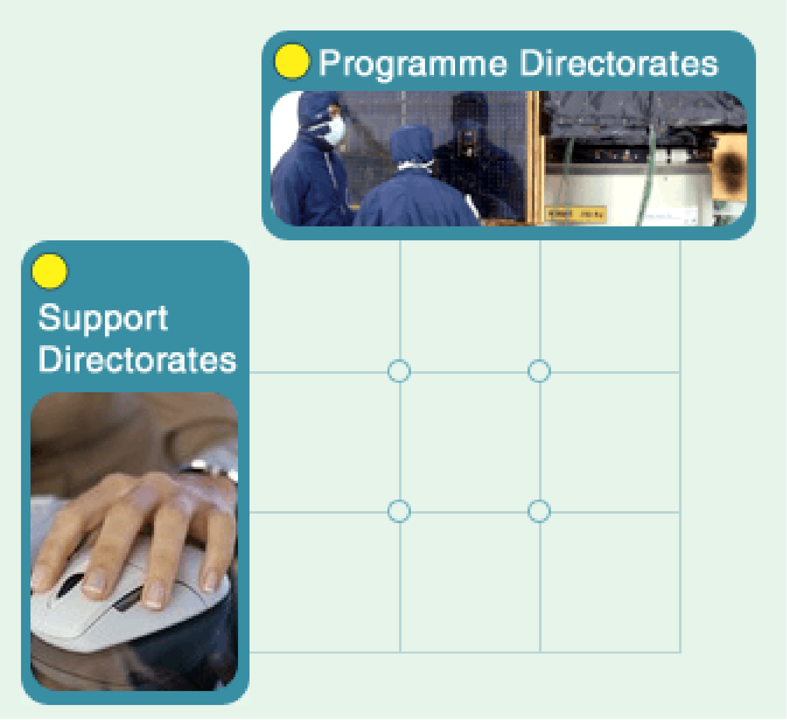


Council: Composed of representatives of the member states (delegates), it is the governing body of the Agency. The Council makes decisions on:

- programs
- finance
- industrial policy

Director General: Appointed by the Council. He is the chief executive officer of the Agency and its legal representative.

ESA – Internal Structure



Vertical directorates related to ESA programs

- D/EOP Earth Observation
- D/GAL Galileo Program and Navigation
- D/HSF Human Spaceflight
- D/LAU Launchers
- D/SRE Science and Robotic Exploration
- D/TIA Telecommunications and Integrated Applications

Horizontal directorates provide functional support to the whole organisation

- D/LEX Legal Affairs and External Relations
- D/OPS Operations and Infrastructure
- D/RES Resources Management
- D/TEC Technical and Quality Management

Sustainable Development at ESA

Sustainable Development (SD) is an ongoing initiative at ESA

Sustainable Development in ESA core activities

- ESA's programmes constitute a tool for sustainable development:
  - Earth Observation and GMES
  - Other initiatives, e.g. Space for Africa, Telemedicine, Eduspace
- ESA recently launched actions and studies
  - A staff consultation on Sustainable Development (call for ideas)
  - A study on the environmental footprint of ESA sites operations
  - A study on environmental regulations and their impact on space programmes

The Agency just set up a new Sustainable Development Office

- To reinforce the coordination between the different ESA functions, activities and actions
- To evaluate them in a future SD Report

The mission of TEC-Q

TEC-Q: Product Assurance and Safety Department, part of Technical and Quality Management Directorate

- Establishment and implementation of quality policies, requirements, and standard
- Provision of expertise and support for product assurance and safety
- Independent assurance function for ESA projects
- Functional responsibility for product assurance and safety personnel
- Coordination of standardization
- Ensure consistency of ESA quality management requirements
- Product Assurance and Safety disciplines comprise Product Assurance management, technical risk management, dependability, safety, quality assurance, EEE components assurance and engineering, materials and processes.

The role of TEC-Q related to SD

Identification of shortcomings in space industrial manufacturing capabilities:

- Sustainable development and related regulations (e.g. RoHS, REACH) may have large impact on availability of materials, processes, and components
- Dependence from single sources, more critical if non-European (e.g. ITAR)
- Production shortfalls
- Production stops

Sustainable development is one element that can lead to deficiencies.

In a more general sense → **obsolescence**

Need to identify risks in early stage for effective mitigation

EEE components

Components development and manufacture may be effected by RoHS and REACH

ESCC: European Space Components Coordination

European System for the qualification and procurement of EEE space parts, based on the partnership between users, manufacturers and agencies.

Under the responsibility of the Space Component Steering Board (SCSB):

- Formulation of harmonized strategic programs and work plans for R&D, evaluation and qualification of EEE space components → Components Technology Board (CTB)
- Definition of ESCC policies and standards → Policy & Standards WG

CTB has watch-dog responsibility and refers specific RoHS and REACH issues to standing or ad-hoc advisory Working Groups.

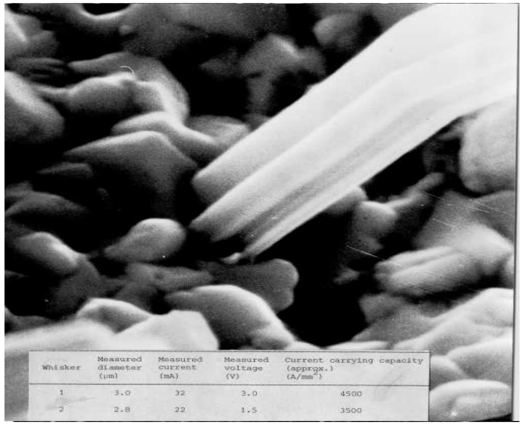
Primary concern: Pb-free → pure Sn terminations – Tin Whisker problem and lead free solders in assembly.

Next issues expected in test methods and production processes.

M&P: Pb free solder

Soldering alloys for space applications contain Pb

- Use of Pb restricted by EC directive 2002/95/EC since 1st July 2006
- To date the military, aerospace, space sector are not directly effected
- Indirect effects may occur from commercial electronics
- Currently Sn/Pb and In/Pb solders are baseline for ESA (ECSS-Q-70-08)



Whisker	Measured diameter (μm)	Measured current (mA)	Measured voltage (V)	Current carrying capacity (approx.) (A/mm^2)
1	3.0	32	3.0	4500
2	2.8	22	1.5	3500

Dunn, B.D. (1997) *Metallurgical Assessment of Spacecraft Parts, Materials and Processes*, Praxis Publishing, Chichester, UK

Alternative soldering alloys are being researched

- Drawbacks in manufacturing and assembly
- Poorer reliability
- Whisker growth (Sn)
- Environmental footprint not necessarily beneficial

Efforts of ESA on alternatives for Pb containing solders continue.

M&P: Protection of Al-Alloys

Protection of lightweight alloys (e.g. Al) is required for applications in space, the requirements are challenging:

- Corrosion (ground environment, human spaceflight)
- Wear, fretting, cold welding
- Vacuum outgassing, UV degradation
- Thermal gradients, adhesion, debris formation
- Thermo-optical properties

Al-alloys are applied with protective finishes, such as (black) anodization:

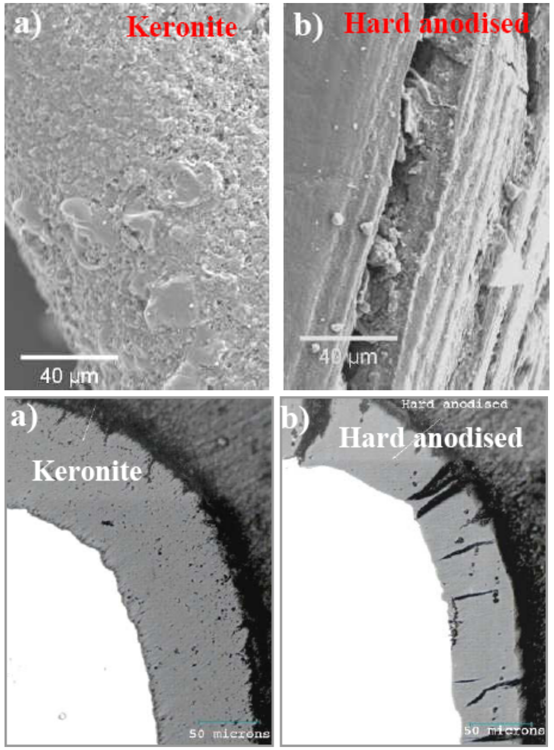
- Organic dyes provide insufficient thermo-optical stability
- Processes use currently Co- and Ni-sulfides via acetate precursors
- Hard anodization processes employ large quantities of strong acids

→ Alternative coating with less environmental impact

Keronite Process I

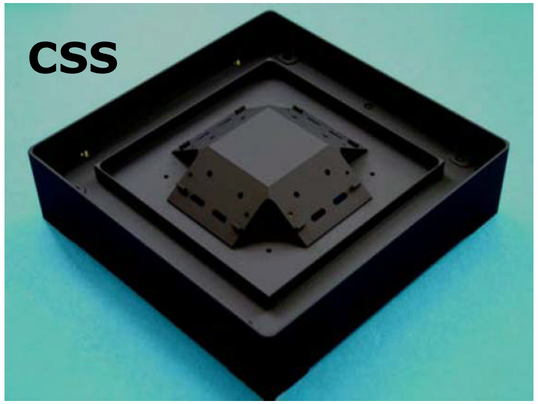
Keronite: Plasma Electrolytic Process for Al and Mg alloys

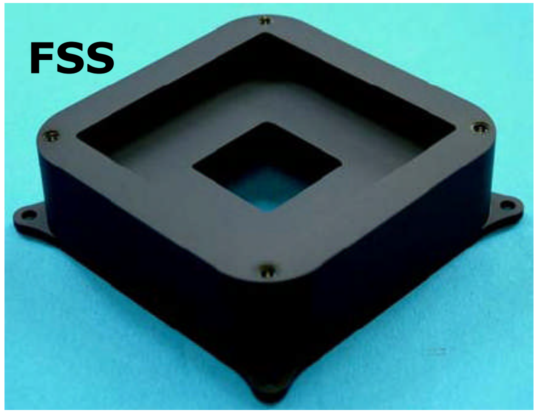
- Pre-treatment: Only degreasing
- Electrolyte: Alkaline, < 4% salt concentration, free of heavy metals
- Potential: 200-900V → plasma oxidation
- Optical appearance: Grey to black, can be made black on Cu containing Al-alloys (e.g. 2219, 7075)
- Porosity < 5%
- Alternative process allows black coating independent of Al alloy, but with porosity of 30-50%
- Very good fretting resistance
- Composite coatings with MoS_2 possible for low friction

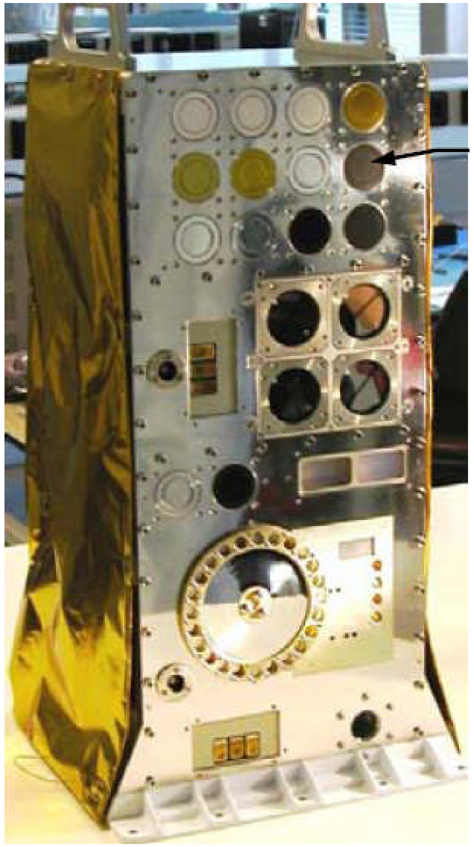


Shrestha, S.; Dunn, B.D. *Surface World* **2007**, 11, 40-44

Keronite Process II







Microcalorimeter on **MEDET**

Material Exposure and Degradation Experiment

Located on EuTEF platform of Columbus laboratory on ISS.

Shrestha, S.; Dunn, B.D. *Surface World* **2007**, 11, 40-44

M&P: Conversion Coatings

Most common surface protection finish of Al alloys is Alodine 1200S

- The process employs Cr(VI) → prohibited by EC directive 2002/95/EC since 1st July 2006
- Space hardware exempted from RoHS directive
  - Large impact on industrial level, also space industry is screening alternatives
  - ESA seeks to comply with RoHS
- Benchmarking study for Cr(VI) free alternatives was conducted, including
  - Alodine 1200S (reference system)
  - Alodine 5700
  - Nabutan STI/310
  - Iridite NCP

  on three different Al alloys: 2219, 5083, 7075

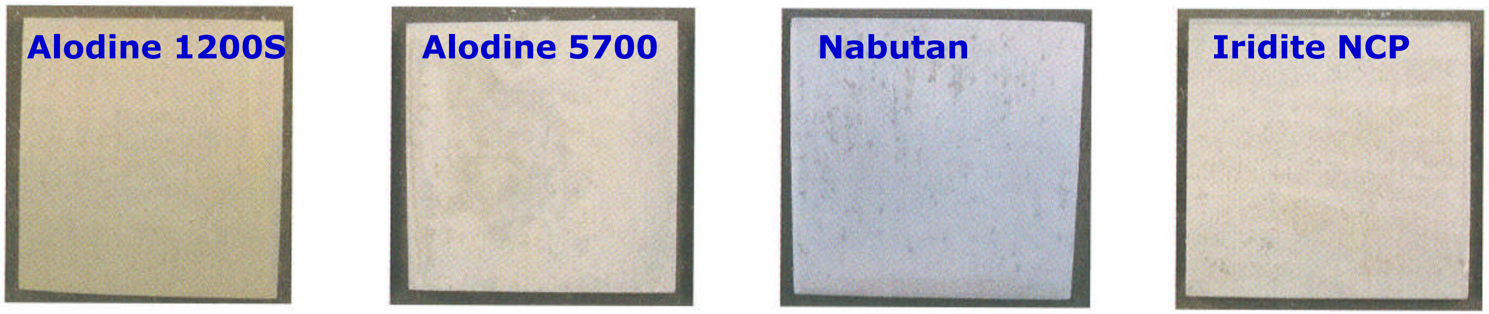
Pereira, A.M.; Dunn, B.D. *ESA STM-276* **2008**, 1-62

Cr(VI)-free Conversion Coatings I

Supplier recommended processes were applied.

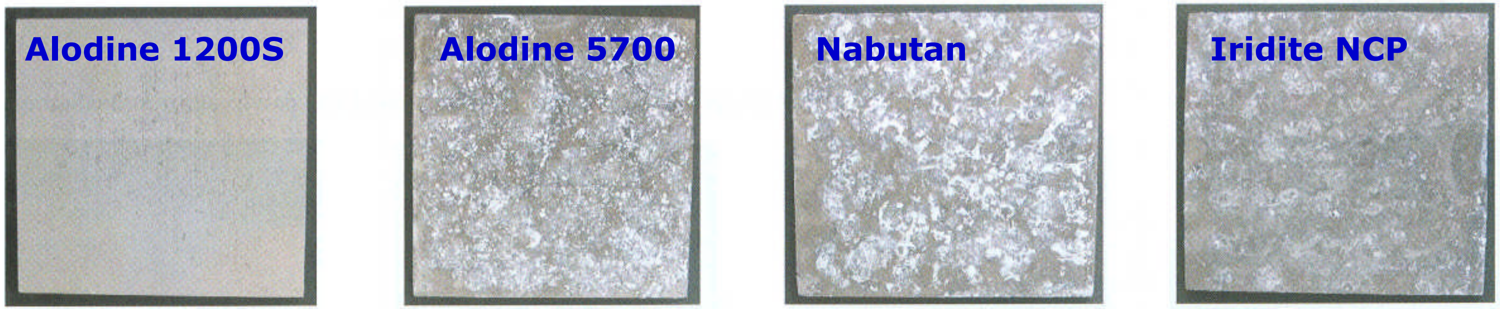
Test matrix:

- Surface roughness
- Surface resistivity
- Thermal cycling (500 cycles between -50°C/+100°C)
- Salt spray (ASTM B117)
- Visual inspection and SEM analysis
- on three different Al alloys: 2219, 5083, 7075

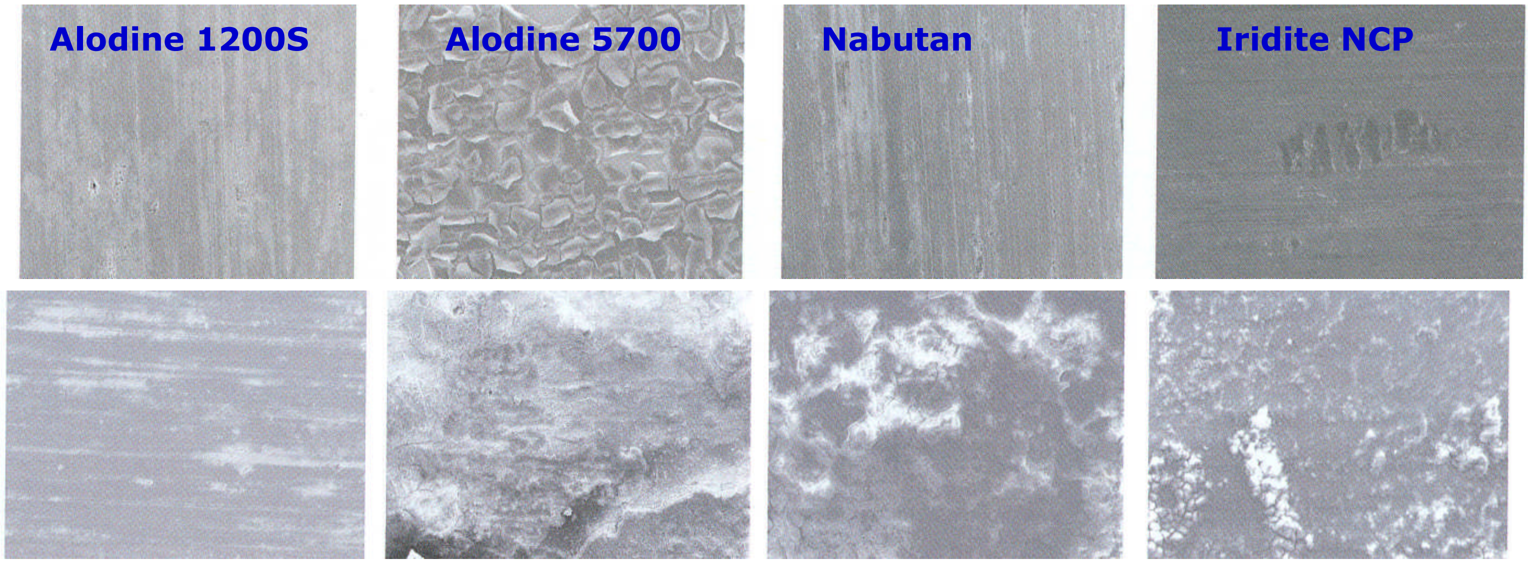


Al7075 after chemical conversion coating treatment (Pereira, A.M.; Dunn, B.D. *ESA STM-276* **2008**, 1-62)

Cr(VI)-free Conversion Coatings II



Coated Al7075 after salt spray test



200x SEM images of coated Al7075 before (top) and after (bottom) salt spray test

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Cr(VI)-free Conversion Coatings III

Conclusions

- Electrical resistively similar for all
- Only Alodine 1200S
  - appeared defect free
  - survived thermal cycling without partial spall-off
  - passed salt spray
  - provided a compact finish

To date no alternative coating can be recommended for space applications. Efforts of ESA on alternatives for Cr(VI) free conversion coatings continue.

Pereira, A.M.; Dunn, B.D. *ESA STM-276* **2008**, 1-62

M&P: Propellant Simulants

CFCs such as Freon 113 are used as propellant simulants during vibrational testing because of similar density to MON

- Large environmental impact due to ozone depleting potential
- Replacement required, promising alternative is HFE 7100
- Materials compatibility assessment required before implementation (stress corrosion cracking

Presentation (A.6.1.) from T. Ghidini

‘Stress-Corrosion Cracking Assessment in Spacecraft Propulsion Systems’

M&P: Paint systems

COUNCIL DIRECTIVE 1999/13/EC (11 March 1999)

on the limitation of emissions of volatile organic compounds (VOCs) due to the use of organic solvents in certain activities and installations

VOC: Vapour pressure of ≥0.01 kPa at 293.15K or at the temperature of application

COUNCIL DIRECTIVE 2004/42/EC (21 April 2004)

on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products and amending Directive 1999/13/EC

VOC: Any organic compound having an initial boiling point less than or equal to 250°C measured at a standard pressure of 101.3 kPa

COUNCIL DIRECTIVE 2002/95/EC (27 January 2003)

on the restriction of the use of certain hazardous substances in electrical and electronic equipment

Prohibition of e.g. Cr(VI) → primers or anticorrosion coatings may be effected

Reduction of VOCs in Paints

Requirements depend on type of coating and application

Example: Primers 450 g/L (1.1.2007), 350 g/L (1.1.2010)

Main concern: Large amount of solvents in paint systems for adjustment/control of viscosity during application as well as morphology of final polymer film.

- Most relevant for large surface area applications (e.g. launchers)
- Reduction of solvent volume $\rightarrow$ impact on base formulation
- Change to solvents of less environmental impact
- Change from organic to aqueous solvent systems

More than 90% in solvent reduction possible.

Conclusions

- Sustainable development is recognized by ESA and related efforts include:
  - Provision of tools for control of sustainable development
  - Internally to review the environmental footprint, impact on space programs
  - Externally to support industry for implementation of new regulations
- ESA is actively supporting space industry to implement regulations related to sustainable development and to take a lead role in the search for alternatives.
- The product assurance and safety department seeks to mitigate the risk of obsolescence in the fields EEE components and M&P. Current activities cover:
  - Alternative solutions for protective and conversion coatings for Al alloys
  - Pb-free solder
  - Propellant simulants
  - Reduction of VOCs in paint systems